TYC 8380-1953-1: Discovery of an RS CVn binary through the *XMM-Newton* slew survey

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ABSTRACT

In this paper we report the discovery of the chromospherically active (RS CVn type) binary TYC 8380-1953-1 through the *XMM-Newton* slew survey and present results of our optical and X-ray follow-up. With a flux limit of 6×10^{-13} erg cm^{-2} s^{-1} in the soft band ($0.2 - 2$ keV), the *XMM-Newton* slew has a similar sensitivity to the *ROSAT* All Sky Survey allowing interesting sources to be identified by their long-term variability. Two different types of stellar sources are detected in shallow X-ray surveys: young stars (both pre-main and main sequence stars) and chromospherically active binaries (BY Dra and RS CVn type systems). The discovery of stars in such surveys and the study of their nature through optical follow-ups is valuable to determine their spatial distribution and scale height in the Galaxy. Our analysis shows that TYC 8380-1953-1 is a double-lined spectroscopic binary with both components having similar spectral type (likely K0/2+K3/5) and luminosity. With a typical coronal temperature for an RS CVn system ($kT \sim 1.15$ keV) and an X-ray luminosity in the 0.3–10 keV energy band higher than 4×10^{31} erg s^{-1}, TYC 8380-1953-1 lies among the most X-ray luminous RS CVn binaries.

Subject headings: Galaxy: stellar content – X-rays: stars – Stars: coronae – Stars: chromospheres – Stars: binaries: spectroscopic – Stars: individual: TYC 8380-1953-1

1. Introduction

The last decade has seen a wealth of wide-area surveys that have led to an explosive increase in our knowledge of the stellar census near the Sun. Despite these advances, our picture of our galactic neighborhood is far from being complete. Three groups can be distinguished that represent the most frequent among the stars: flare stars, active binaries and isolated young stars in the solar neighborhood. The census and space density of all three groups is unknown. Reid et al. (2004)

estimate that the 20 pc census of late-type dwarf stars, which include the dMe flare stars, is still incomplete to $\sim 20\,\%$, and obviously for larger distances there is a much higher fraction of missing stars. The most recent version of the *Catalog of chromospherically active binary stars* (CAB; Eker et al. 2008) comprises 409 systems. Almost 50 % of the stars in this post-*Hipparcos* version of the CAB are new identifications with respect to the previous catalog of Strassmeier et al. (1993). Finally, the systematic search of isolated young T Tauri stars, i.e. pre-main sequence stars located far from present-day star-forming regions, started with the discovery of the prototypical object TW Hya (Rucinski and Krautter 1983). To date, the TW Hya association consists of a total of 30 spectroscopically confirmed members, and the existence of 8 other nearby young associations ($d < 100$ pc, age < 50 Myr) has been established (Torres et al. 2008). However, our knowledge of the stellar content of these associations is very incomplete due to their large extent of tens of square degrees on the sky resulting from the close distance.

A common feature of all three groups of stars is that they are characterized by strong magnetic activity and, therefore, they stand out in X-ray surveys. In the past, magnetically active stars have been discovered by the time-profile of their X-ray emission (outbursts lasting one to several hours), a thermal X-ray spectrum of ~ 1 keV typical for stellar coronae and subsequent confirmation with optical spectroscopy (e.g. Hambaryan et al. 2004; Kennea et al. 2007). Several types of astrophysical sources can cause variations of the X-ray signal by factors of 100 over short and/or long timescales. Therefore, for X-ray sources discovered during the *ROSAT* All Sky Survey (RASS) or short snapshot observations, deep pointed X-ray follow-up observations provide constraints that are useful to discriminate between various candidate classes on basis of the luminosity, variability behavior and X-ray spectroscopy. Soft sources, e.g., must be associated with relatively low absorption and are likely of galactic origin. Even if the stellar nature can be established through the X-ray properties, optical follow-up spectroscopy is needed for deriving, amongst others, the spectral type, luminosity class, rotational and multiplicity state.

We have followed this approach, and present here the discovery of an active binary system from multi-epoch X-ray observations and subsequent optical follow-up spectroscopy. Our target was recently identified as an X-ray bright object in the *XMM-Newton* slew survey (XMMSL). Across the history of X-ray astronomy slew surveys have proven to be useful complements to all-sky surveys and deep pointings. For the first XMMSL catalog (Saxton et al. 2008) more than 200 satellite slews have been analysed, covering $\sim 14\,\%$ of the sky and yielding 2692 X-ray sources down to a soft band ($0.2 - 2$ keV) flux limit of 6×10^{-13} erg cm^{-2} s^{-1}. This is within a factor two of the sensitivity of the RASS. One of the most important contributions of slew surveys is the discovery of variable sources. Various types of astrophysical sources were identified after optical follow-up of XMMSL transients, e.g. supermassive black holes (Esquej et al. 2007) and novae (Read et al. 2008). We show here that the XMMSL can also be used to identify stars.

In this work, we determine the nature of TYC 8380-1953-1, identified as a transient X-ray source in a recent *XMM-Newton* slew. We have carried out a pointed *XMM-Newton* observation of TYC 8380-1953-1 with the aim to detect its quiescent, i.e. non-flaring, X-ray emission. With two high-resolution optical spectra obtained with FEROS at the 2.2m ESO telescope on La Silla we intended to (1) infer its age by measuring the Lithium abundance (6708 Å), (2) determine its rotation rate ($v \sin i$) as additional evidence for age/activity, (3) and establish or refute its membership in any of the known young stellar associations in the solar neighborhood by studying the kinematics or find evidence for binarity from radial velocity (RV) variations.

2. Observations

2.1. *XMM-Newton* slew and previous knowledge on the source

On Sep 24, 2011 bright X-ray emission associated with TYC 8380-1953-1 was detected during an *XMM-Newton* slew (slew-ID. 9215900005; source-ID. XMMSL1 J192252.3-483210). TYC 8380-1953-1 is a fairly unknown star with $B-V = 0.8$ mag ($V = 10.6$ mag), corresponding to early-K spectral type for a dwarf. Making use of stellar evolutionary models, we estimated a photometric

distance of $\sim 100\,\mathrm{pc}$ for an assumed age between 100 Myr and 1 Gyr. The same color for a giant star would correspond to an approximate spectral type G3. In such case, the star would be more distant ($d \sim 900$ pc, assuming $M_{\mathrm{V}} = 0.9$ mag; see Schaifers and Voigt 1982). The only additional information available on this object are the coordinates and proper motion from Tycho. The sky position of TYC 8380-1953-1 makes it a candidate of the AB Dor association. The AB Dor group is one of the oldest young nearby associations ($\sim 30 - 50\,\mathrm{Myr}$; López-Santiago et al. 2006) and hosts several suspected RS CVn or BY Dra variables (see summary in Torres et al. 2008). These kind of variable stars are characterized by strong magnetic activity and fast rotation related to synchronization with the orbital period in binary systems. Nothing was known about the multiplicity of TYC 8380-1953-1 prior to our campaign.

TYC 8380-1953-1 was detected with 17 counts during an *XMM-Newton* slew. All the slew observations are made with the EPIC/pn using the medium filter. This slew source caught our attention because of its non-detection in the RASS. We have extracted a spectrum from a circle of radius $30''$ centered on the source with the background being extracted from an annulus of inner radius $60''$ and outer radius $90''$ around the source. The detector matrices were calculated taking into account the transit of TYC 8380-1953-1 across the detector using the method described in Read et al. (2008). A $0.3 - 2.0\,\mathrm{keV}$ count rate of $1.09 \pm 0.29\,\mathrm{cts/s}$ is obtained. Spectral fitting is prohibited given the poor statistics. However, we compare the slew spectrum to the best-fit model obtained from our pointed follow-up *XMM-Newton* observation (described in detail in Sect. 2.2). For this exercise, all spectral parameters (temperature kT, column density N_{H} and abundance Z) were held fixed at the values derived from the *XMM-Newton* pointing and the normalization was set to $N_{\mathrm{slew}} = N_{\mathrm{poin}} * CR_{\mathrm{slew}}/CR_{\mathrm{poin}}$ where CR are the observed $0.3 - 2.0\,\mathrm{keV}$ count rates for the slew and the pointing, respectively and N the normalizations of the spectral model. The result is displayed in Fig. 1 and shows that the spectral shape during the *XMM-Newton* slew is compatible with that derived from the pointed observation. However, during the slew the count rate – and consequently the flux – was about a factor three larger.

The $2\,\sigma$ upper limit from the RASS for TYC 8380-1953-1 is $0.039\,\mathrm{cts/s}$, which is equivalent to $0.31\,\mathrm{cts/s}$ in the energy band 0.3–2.0 keV for the *XMM-Newton* EPIC/pn with thin filter and $0.32\,\mathrm{cts/s}$ in *XMM-Newton* EPIC/pn with medium filter, assuming the spectral model from Sect. 2.2. This is on the order of the count rate measured during the *XMM-Newton* pointing, i.e. this upper limit does not provide any information on source variability.

2.2. *XMM-Newton* pointed observation

We have been granted an *XMM-Newton* target-of-opportunity observation of TYC 8380-1953-1. This observation was performed in October 13$^{\mathrm{th}}$ 2011, during revolution 2169 (obs. id. 0679380601). The European Photon Imaging Camera (EPIC), operated in full-frame mode, was used as primary instrument. The exposure times for the PN and MOS detectors were 5 and 6.6 ks, respectively. The X-ray background level remained constant at a low rate during the entire observing period. This pointed *XMM-Newton* observation was designed to be 400 times more sensitive than the *XMM-Newton* slew data.

Data reduction was performed with the latest version of the XMM-*Newton* specific software for data reduction and analysis (Science Analysis System, SAS, version 11.0). Filtered event lists for EPIC MOS and PN were produced following the SAS standards. We do not use data from the Reflection Grating Spectrometer (RGS) because the source has not enough counts to perform an analysis. The event lists contain information on the arrival time of each photon detected during the observation, its energy and position on the detector. We used EVSELECT to obtain the X-ray spectrum of the source identified with the star TYC 8380-1953-1. We chose a circular extraction region of radius $27''$ encircling 80% of photons in the $0.3-10.0$ keV EPIC energy band. Background was extracted from a local source-free region using the same extraction region radius than for the source. The light curve of TYC 8380-1953-1 was extracted from the X-ray event list using the same extraction region than for the spectrum, with an IDL code specifically created by us. The analysis of the X-ray spectrum and light curve of our target is presented in Section 3.1.

2.3. Optical spectroscopy

Optical spectroscopic observations of TYC 8380-1953-1 were carried out on 9^{th} and 10^{th} November 2011. We used the high-resolution spectrograph FEROS, mounted on the 2.2m telescope of the La Silla Observatory of the European Southern Observatory. The chosen configuration provides $R \sim 50000$ at 6562 Å, measured from the FWHM of comparison-arc emission lines. FEROS covers the entire optical spectral range from 3650 to 8900 Å.

One spectrum of the star was taken during each of the two nights, together with a spectrum of the reference star β Ceti, a spectral type and radial velocity standard K0 giant. The exposure time for the target was 634 s in both observations, giving a signal-to-noise ratio $S/N \sim 30$ in Hα, Na I doublet and Hβ lines and $S/N \sim 10$ in Ca II H & K. The maximum S/N ratio in those spectra is ~ 55, that was reached at red wavelengths ($\lambda > 7000$ Å). The S/N for the reference star ranges from 100 to 200, from blue to red wavelengths.

The data reduction process was performed using the standard procedures in the IRAF[1] package (bias subtraction, extraction of scattered light produced by optical system, division by a normalized flat-field and wavelength calibration). After reduction, each spectrum was normalized to its continuum, order by order, by fitting a polynomial function. Despite the good quality of the flat-field spectra, the fringing pattern could not be completely removed from the stellar spectra. This problem affected only long wavelengths of the star's spectrum, where the Ca II IR-triplet is located. Therefore, no analysis of those spectral lines was done.

3. Data analysis

3.1. X-ray spectrum and light curve

For the analysis of the X-ray spectrum of TYC 8380-1853-1, we used the C-code based software XSPEC (v.12; Arnaud 2004) with a plasma model calculated using the Astrophysical Plasma Emission Database (APED), that is included in AtomDB[2]. The reference spectrum generated by XSPEC is that of a collisionally-ionized diffuse gas. To account for the interstellar and/or circumstellar absorption in the line of sight of the source, XSPEC permits to use an absorption (multiplicative) model in combination with the plasma model. For our analysis, we used *wabs*, a photo-electric absorption law determined with the Wisconsin (Morrison and McCammon 1983) cross-sections.

As observed in the Sun, the corona of any star shows an X-ray spectrum that is fully characterized by its emission measure distribution. At the energy resolution of the EPIC, the spectrum of a coronal source is well-represented by one or two thermal components (Briggs and Pye 2003; López-Santiago et al. 2007). Multi-temperature models with three or more thermal components are needed only when the statistics very high (e.g. Robrade and Schmitt 2005; López-Santiago et al. 2010a).

For our target, TYC 8380-1953-1, we collected ~ 3000 counts in total summing up photons of the PN and MOS cameras in the energy range 0.3–10.0 keV, The spectrum is shown together with the best one- and two-temperature fits in Fig. 2 and Table 1 summarizes the best fit parameters. The reduced χ^2 (column 7 of Table 1) shows that the one-temperature model provides a good description of the spectrum. Adding a second thermal component to the model does not give further information, except for a better fit to the hard X-ray tail of the spectrum. However, the additional hot temperature is not well constrained and this component contributes very little to the spectrum in the EPIC energy range (the emission measure ratio between both thermal components is $EM_1/EM_2 \sim 7$; see Table 1). The value of the column density measured from the X-ray spectrum is comparable with the Galactic column density at 1 Kpc in the line of sight out of the Galactic disk (Kalberla et al. 2005). This result suggests that the star is not nearby (see also Sections 3.2.1 and 4).

In Fig 3, we plot the EPIC/PN lightcurve of TYC 8380-1953-1 in $0.3 - 10$ keV. Bins in the figure are four minutes long. The lightcurve is background corrected. A Kolmogorov-Smirnov test

[1] IRAF is distributed by the National Optical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

[2] http://www.atomdb.org/

gives very high probability for the star's count-rate to be constant throughout the observation ($P > 95\%$). The observation is by far not long enough to detect rotational modulation or eventual variations during orbital phase; see Sect. 4 for an estimate of the period.

3.2. High-resolution optical spectrum

A simple visual comparison of the spectra of TYC 8380-1953-1 observed during both nights shows that the star is a double-lined spectroscopic binary system (SB2; see Fig. 4). During the first observing night, the spectral lines of the two stars in the system were blended. During the second night, both spectral components were clearly separated. The strength of iron and calcium lines of the secondary star is slightly lower than that of the primary but the ratio between lines in both stars is very similar, what suggests that both stars have similar spectral types. In the remainder of this section we determine spectral type, RV and rotation rates and examine the chromospheric activity of both components in the binary. Tables 2 and 3 summarize the results obtained from the optical spectral analysis.

3.2.1. Spectral types, radial velocities and rotation

To determine the spectral types of both stars in the binary system, we followed López-Santiago et al. (2010b). We first studied different spectral type and luminosity class indicators, including spectral line ratios and equivalent widths. In particular, we used the lines Ti I λ5866 Å, the Mg I triplet at λ5167, 5172 and 5183 Å, Fe I λ6430 Å, Fe II λ6432 and 6457 Å, Ca I λ6439, 6449 and 6456 Å, Co I λ6455 Åand V I λ6452 Å, as described in Strassmeier and Fekel (1990), Montes et al. (2007) and Gray and Corbally (2009). From the different line ratios, we conclude that both stars in the binary system are of early-K spectral type. However, the large broadening of the line profiles prevents the precise determination of the spectral sub-types. We tentatively classify the system as K0/2+K3/5.

The Na I doublet at 5890 Å is a good indicator of gravity for some spectral types (e.g. Montes et al. 1999). In particular, the wings of these lines become narrower in evolved K and M stars (giants or subgiants). Also good indicators of gravity are strong lines like the Ca I lines at 4227 and 6162 Å (Gray and Corbally 2009). In our spectra those lines are blended with other spectral lines due to rotational broadening. The situation is even worse because TYC 8380-1953-1 is a SB2 system and the lines of both components are present in the spectra. Other typical indicators of gravity such as the Balmer series and the Ca II H & K lines are not useful for active stars since their profiles are affected by the presence of chromospheric emission. The profile of the Na I doublet lines indicates that both components of TYC 8380-1953-1 are evolved. This hypothesis is confirmed during the spectral subtraction process (see below). The spectrum of TYC 8380-1953-1 at the position of the Na I doublet during the second night is shown in Fig. 5. During this observation, it showed the lines of both stars in this binary system and a narrow absorption line produced by the interstellar medium present in between the star and the Earth. This is demonstrated in Fig. 5 bottom, where we show the spectrum that remains if the photospheric spectrum of the two stars in the binary are subtracted (see bellow for a description of the subtraction technique). We have measured the equivalent width of these interstellar Na I lines, and obtained $EW = 0.148 \pm 0.006$ Å. Using the relations of Munari and Zwitter (1997), $E(\mathrm{B-V}) \approx 0.05 \pm 0.01$ mag ($A_{\mathrm{V}} = 0.16 \pm 0.01$ mag), corresponding to a column density $N_{\mathrm{H}} = 3.6 \pm 0.1 \times 10^{20}$ cm^{-2} (see Gorenstein 1975). This value is marginally compatible with that obtained from the X-ray spectral fitting ($N_{\mathrm{H}} \approx 7 \pm 3 \times 10^{20}$ cm^{-2}; see Table 1).

To complete our analysis of the optical spectra of TYC 8380-1853-1, we performed spectral subtraction of a spectral type standard star on our target using JSTARMOD, a perl-plus-fortran code based software that permits to combine the spectra of different objects and perform subtraction on the spectrum of another object (the interested reader will find a detailed discussion on the spectral subtraction technique and the use of JSTARMOD in López-Santiago et al. 2010b, Sections 3.4 and 3.5). The spectral type standard K0 giant β Ceti was used as the reference star. β Ceti was observed together with our target during each night. JSTAMOD permits to use more than one reference star (with different weights) to reproduce

the spectrum of binary systems. We used β Ceti as the reference star for both components of TYC 8380-1853-1, since they have very similar spectral types. The fit was performed separately for each night. The results of the fits are shown in Table 2. The rotational velocities of both components for the first night (where their spectral lines where blended) were fixed to the values obtained for the second night. The radial velocities given in Table 2 are relative to the standard star. Additional observations are needed to determine precisely the binary orbit and stellar parameters, in particular the stellar masses. The rms values given in column 8 of Table 2 were measured in the subtracted spectrum and they account for the errors in the fitting as well as for possible differences in the spectral type of the two stellar components of TYC 8380-1953-1 and the reference star β Ceti (see López-Santiago et al. 2003, for details).

3.2.2. Chromospheric activity

The spectrum of TYC 8380-1953-1 shows several chromospheric lines in emission. The Hα line shows an inverse P Cygni profile caused by the superposition of the absorption line of the primary and the emission line of the secondary (see Fig. 6). In fact, the primary presents a filled-in Hα line instead of a pure absorption line. This is easily seen when the spectrum is compared with that of the reference star (Fig. 7). We used β Ceti as reference for the subtraction of the photosphere of both components of TYC 8380-1953-1. Radial and rotational velocities were fixed to the values determined in Section 3.2.1. We then fitted the subtracted Hα spectrum of each night with two Gaussian functions using the IRAF task SPLOT. The results are shown in Fig. 8 and Table 3. The values given in Table 3 are corrected for the different contribution of each star to the continuum.

The H_β line also shows some evidence for filling-in of its core but the subtracted spectrum is too noisy to perform a quantitative analysis. The Ca II H & K lines are detected in emission, but the low S/N ratio in this specific spectral region in our observations prevented us from applying the spectral subtraction technique. In Fig. 9 we compare the observed spectrum of TYC 8380-1953-1and β Ceti in the region of the Ca II H line. No other chromospheric lines are detected in emission, nor are there any signs for filling-in of photospheric lines of the Balmer series other than Hβ. However, the presence of weak emission lines in the spectrum of TYC 8380-1953-1 cannot be excluded as the S/N ratio of our observation is not high enough to detect them.

4. Discussion and conclusions

Precise classifications of suspected galactic stars are important for a correct assessment of the space density of various types of stars, such as flare stars, young nearby stars and active binaries. Our X-ray and optical follow-up observations of the *XMM-Newton* slew transient XMMSL1 J192252.3-483210, identified with the Tycho source TYC 8380-1953-1, have allowed us to constrain the nature of this star.

First, we can exclude that TYC 8380-1953-1 is a flaring dwarf star (dMe) in the solar neighborhood because of the signatures of low gravity found in the optical spectrum (narrow Na I doublet). Secondly, we can discard the hypothesis that TYC 8380-1953-1 is a member of a young stellar association or moving group in the solar neighborhood based on the following arguments. Assuming a typical absolute magnitude for a giant K star ($M_{\rm V} = 0$) and that both components have very similar luminosity ($V = 10.6$ mag for the binary system), the distance to TYC 8380-1953-1 can be estimated to be close to 2 kpc ($d \sim 1$ kpc for $M_{\rm V} = 2$, typical of less luminous giants and subgiants). Even in the most optimistic case (assuming that the stars are low luminous subgiants), the distance to TYC 8380-1953-1 would be approximately 600 pc. Moreover, both the column density determined from the equivalent width of the narrow Na I doublet components observed in the stellar spectrum and that obtained from the X-ray spectrum, indicate significant interstellar extinction, i.e. the system is not nearby. Finally, another proof against this hypothesis is the absence of the lithium absorption line at 6708 Å.

Our sequence of two optical spectra obtained in two consecutive nights has shown strong RV variations indicating binarity. Since the stars in the system are evolved, we conclude that TYC 8380-1953-1 is an RS CVn binary. These kind of systems typically consist of an evolved chromospherically active cool star (spectral type G or later) and a hotter component, evolved or not and usually inactive

(Fekel et al. 1986). However, several RS CVn systems consist of two evolved stars of similar spectral type (see the chromospherically active binaries (CAB) catalog by Eker et al. 2008), as we observed for TYC 8380-1953-1 where both components have early-K spectral type and present chromospheric activity evidenced by the presence of optical emission lines. The stellar parameters of TYC 8380-1853-1 are compatible with other chromospherically active binary systems such as DK Dra, an SB2 of spectral type K1 III + K1 III (Montes et al. 2000). Similar to TYC 8380-1953-1, DK Dra shows filled-in Hα profiles and Ca II H & K in emission for both components. A recent list of typical parameters of chromospherically active binaries is compiled in the CAB catalog.

The X-ray properties of TYC 8380-1953-1 are also consistent with this classification as an active binary. At a distance between 600 pc and 2 kpc, the observed X-ray flux during the *XMM-Newton* pointing corresponds to an X-ray luminosity of 4×10^{31} and 5×10^{32} erg s^{-1}, respectively, at the upper end of the range observed for RS CVn systems in the CAB. It is definitely higher than that of nearby K-type field dwarf stars ($10^{27.5}$ erg/s; Schmitt and Liefke 2004). It is also at the upper end of the range observed for the RS CVn systems that have values in the CAB. This can be seen in Fig. 10 where we show TYC 8380-1953-1 (vertical bar) together with various sub-samples of RS CVn systems listed in the CAB. This result is in favor of the lower of the two distances given above for TYC 8380-1953-1. During the *XMM-Newton* slew, the X-ray luminosity was a factor of three higher than during the pointed observation. The star likely underwent a flare during that time. Although this hypothesis cannot be reliably demonstrated with the current data, the X-ray luminosity of TYC 8380-1953-1 during the *XMM-Newton* slew is higher than the flare peak luminosities reported by Pandey and Singh (2012) for other RS CVn binary systems.

The coronal temperature of TYC 8380-1953-1 (kT $\sim$ 1.15 keV, T $\sim$ 12 MK) is typical of both RS CVn and BY Dra binary systems (Dempsey et al. 1993a,b), although similar coronal temperatures are also observed in single late-type dwarf stars (e.g. Favata and Micela 2003; Güdel 2004). Generally, the X-ray luminosity of late-type stars is linked with the rotation period in a so-called rotation-activity relation where fast rotation goes along with strong X-ray emission (Pallavicini et al. 1981; Pizzolato et al. 2003). There is no consensus in the literature on the question if RS CVn binaries follow a rotation-activity connection (e.g. Walter and Bowyer 1981; Fleming et al. 1989). Possibly this is due to the incompleteness and biases of all RS CVn samples examined so far. Fig. 10 demonstrates this on the basis of the most recent compilation of RS CVns in the CAB catalog The total CAB sample is biased towards stars with high X-ray luminosity, which are absent in the known 50-pc sample. The restricted sample within 50 pc, presents some evidence for a rotation-activity connection (no low-activity stars have fast rotation). Note, that possibly not even the 50 pc is complete, and that systems with a range of spectral types are included in the CAB. In fact, this catalog contains only three TYC 8380-1953-1 analogs, i.e. RS CVn binaries composed of two K-type stars. These are highlighted with star symbols in Fig. 10. We conclude that TYC 8380-1953-1 is the most active of the known systems in a rare group of active binaries.

Finally, the chromospheric emission level observed for both components of TYC 8380-1953-1 is similar to that obtained for chromospherically active binaries, whether evolved or not (e.g. Montes et al. 2000; Gálvez et al. 2007). We can speculate on the origin of the large difference in the equivalent width of Hα (see Table 3) of the secondary star for the two nights. One possibility is that its chromospheric emission level may have changed because active regions have moved into the line-of-sight as a result of rotation. (Recall that the 25 h interval between the two spectra likely represents a significant fraction of the stellar rotation cycle). Another possibility is that during the first night, the primary star was eclipsing the secondary. Last but not least, it is also possible that both stars have chromospheric activity in that part of the stellar disk facing the other star. However, the periodic flaring in loop systems in between two close binary stars predicted by MHD simulations (Gao et al. 2008) have not been confirmed by observations (Stelzer et al. 2002).

The discovery of RS CVn type binaries, such as TYC 8380-1953-1, is important because the Galactic scale height of these objects is poorly known. In several works (e.g. Favata and Micela 2003;

Micela et al. 2007; López-Santiago et al. 2007) it was noticed that shallow X-ray surveys show an excess of 'yellow' stars when compared to Galactic models. In optical follow-ups of the stellar X-ray sources in those surveys, several authors have demonstrated that part of that excess is produced by the presence of evolved binaries, that are not well accounted for by the present Galactic models (Sciortino et al. 1995; Affer et al. 2008, López-Santiago et al. 2012 in prep.) We have here identified one such binary system.

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Table 1: Results of the spectral fit of a 1T- and 2T-models to the observed X-ray spectrum of TYC 8380-1953-1. Errors are at 90% confidence level ($\Delta\chi^2 = 2.7$).

Numer of thermal components	$N_{\rm H}$ ($\times 10^{22}$ cm^{-2})	kT_1 (keV)	kT_2 (keV)	EM_1/EM_2	Z ($Z_\odot$)	$\chi^2_{\rm red}$ (d.o.f)	$f_{\rm X}^{\rm observed}$ (erg cm^{-2} s^{-1})	$f_{\rm X}^{\rm unabsorbed}$ (erg cm^{-2} s^{-1})
1	$0.07^{+0.03}_{-0.01}$	$1.15^{+0.07}_{-0.14}$	...	...	$0.10^{+0.03}_{-0.05}$	1.06 (176)	7.0×10^{-13}	9.2×10^{-13}
2	$0.07^{+0.02}_{-0.01}$	$0.99^{+0.05}_{-0.06}$	$17.2^{+17.2}_{-13.4}$	6.9	$0.11^{+0.05}_{-0.04}$	0.86 (174)	8.4×10^{-13}	1.0×10^{-12}

Table 2: Results of the cross-correlation of TYC 8380-1953-1 with the K0 III standard star β Ceti.

Night	Radial velocity		Rotational velocity		weight		rms
	primary (km s^{-1})	secondary (km s^{-1})	primary (km s^{-1})	secondary (km s^{-1})	primary (km s^{-1})	secondary (km s^{-1})	
1	12.4	36.7	34.1	24.8	0.6	0.4	0.02
2	21.5	-54.3	34.1	24.8	0.6	0.4	0.02

Table 3: Summary of the stellar parameters of TYC 8380-1953-1 from the analysis of the high-resolution spectrum.

Parameter	value	
	primary	secondary
Spectral type	K0/2	K3/5
Luminosity class	IV/III	IV/III
$v \sin i$ [km s^{-1}]	34 ± 3	25 ± 2
$EW(\rm H_\alpha)$ [Å] (Nov 9)	0.92 ± 0.04	1.08 ± 0.08
$EW(\rm H_\alpha)$ [Å] (Nov 10)	0.59 ± 0.03	3.30 ± 0.09

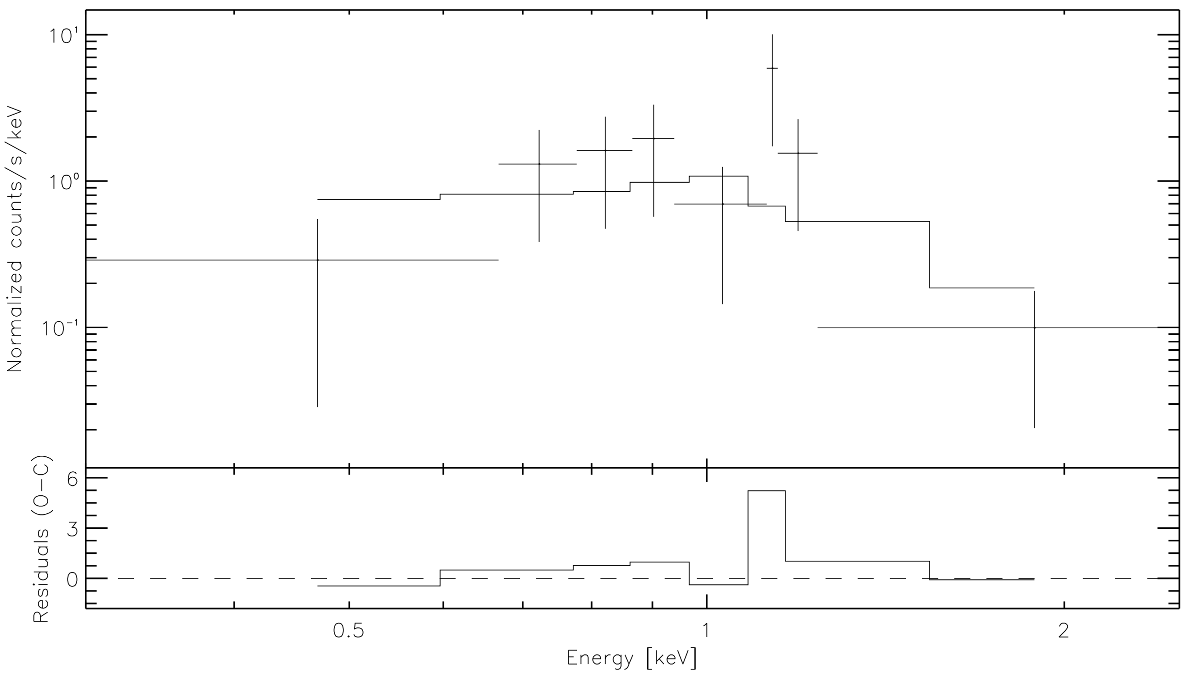

Fig. 1.— X-ray spectrum of TYC 8380-1953-1during XMM-*Newton* slew compared to the best-fit model obtained from our pointed observation. The normalization is scaled to $N_{\rm slew} = N_{\rm poin} * CR_{\rm slew}/CR_{\rm poin}$. The remaining parameters are fixed to those obtained from our pointed observation.

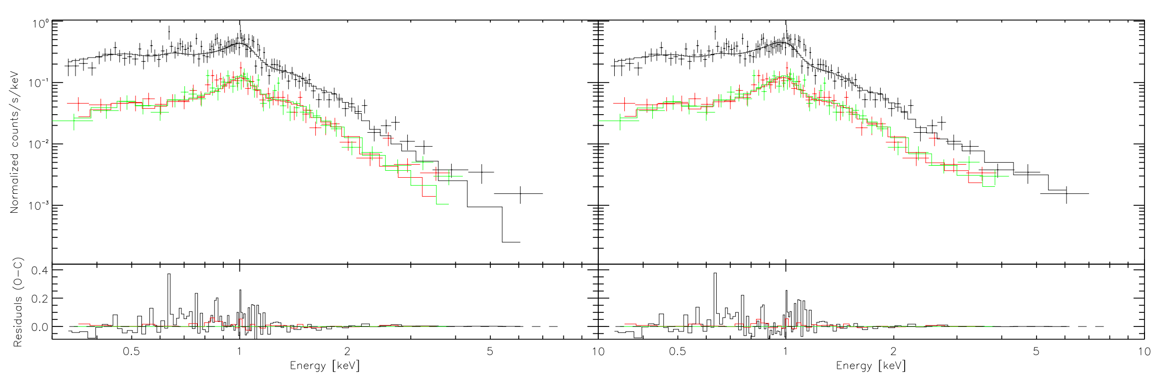

Fig. 2.— EPIC PN (black) and MOS (red and green) spectra of TYC 8380-1953-1 in the energy range $0.3-10.0$ keV. Continuous lines represent the model fitted with XSPEC using plasma models with one temperature (left panel) and two temperatures (right panel), respectively.

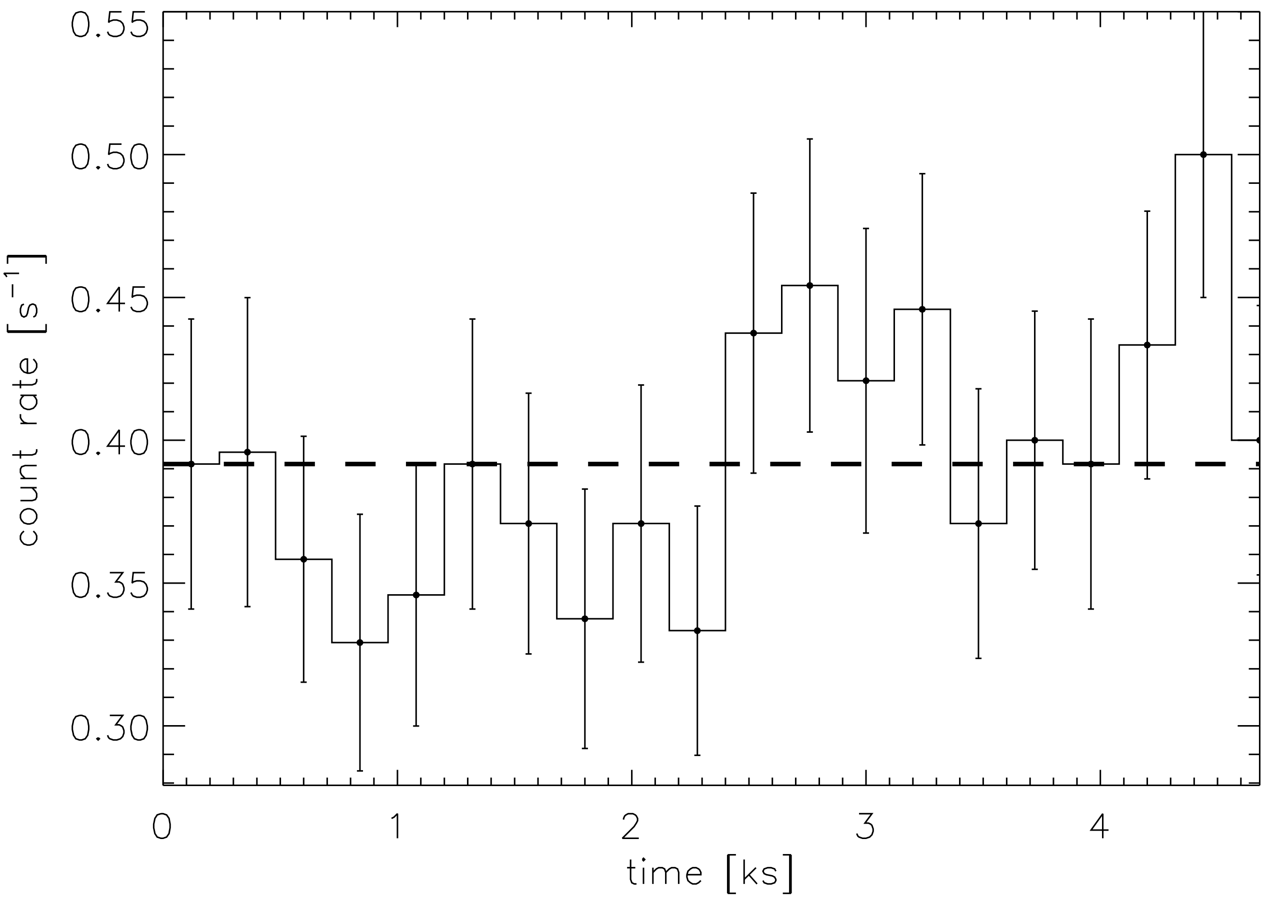

Fig. 3.— X-ray lightcurve of TYC 8380-1953-1 in the $0.3 - 10$ keV energy range observed with EPIC PN. Time bins are 4 minutes long. The dashed line is the mean count-rate of the source.

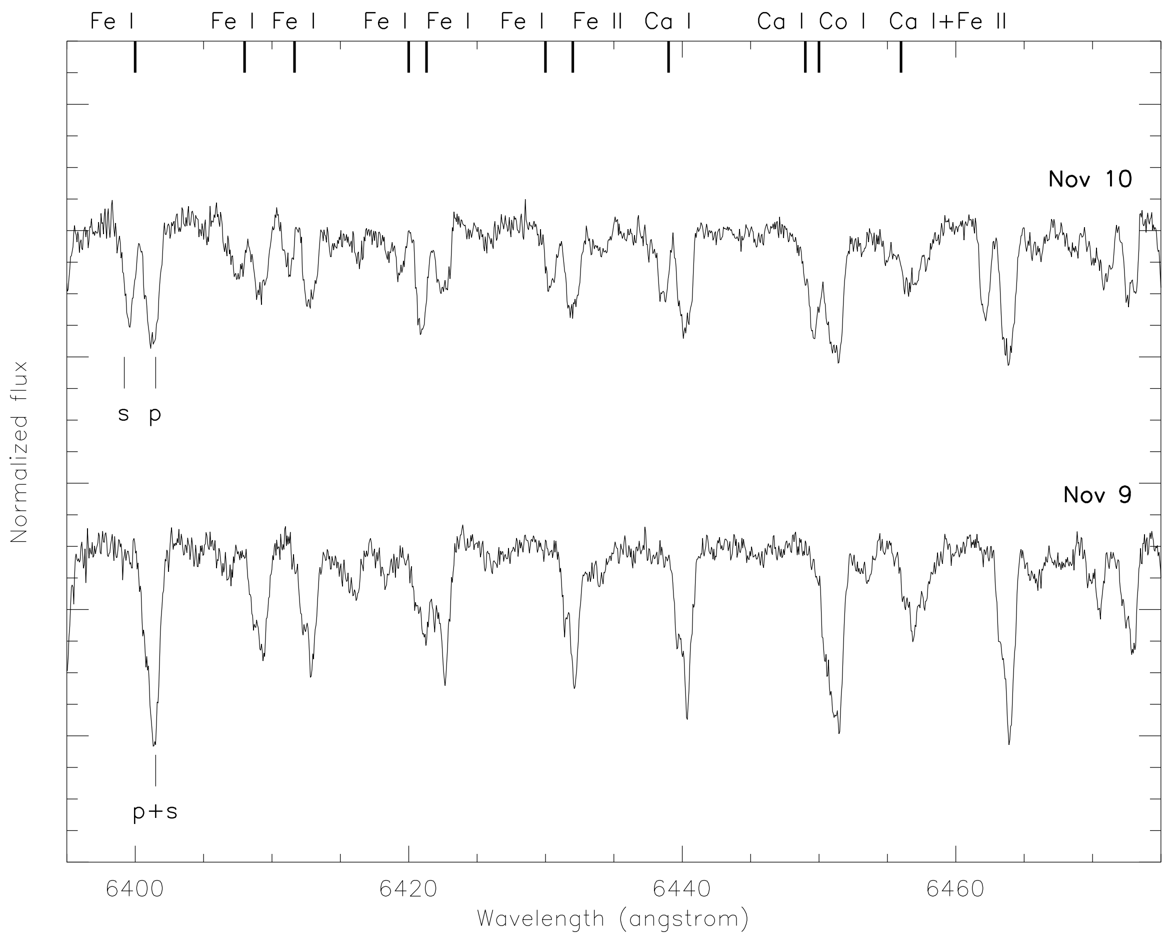

Fig. 4.— Normalized spectrum of TYC 8380-1953-1 close to the Hα line observed on Nov 9 and 10, 2011. All the lines observed in the displayed part of the spectrum are from Ca I and Fe I. We mark laboratory position for some representative lines.

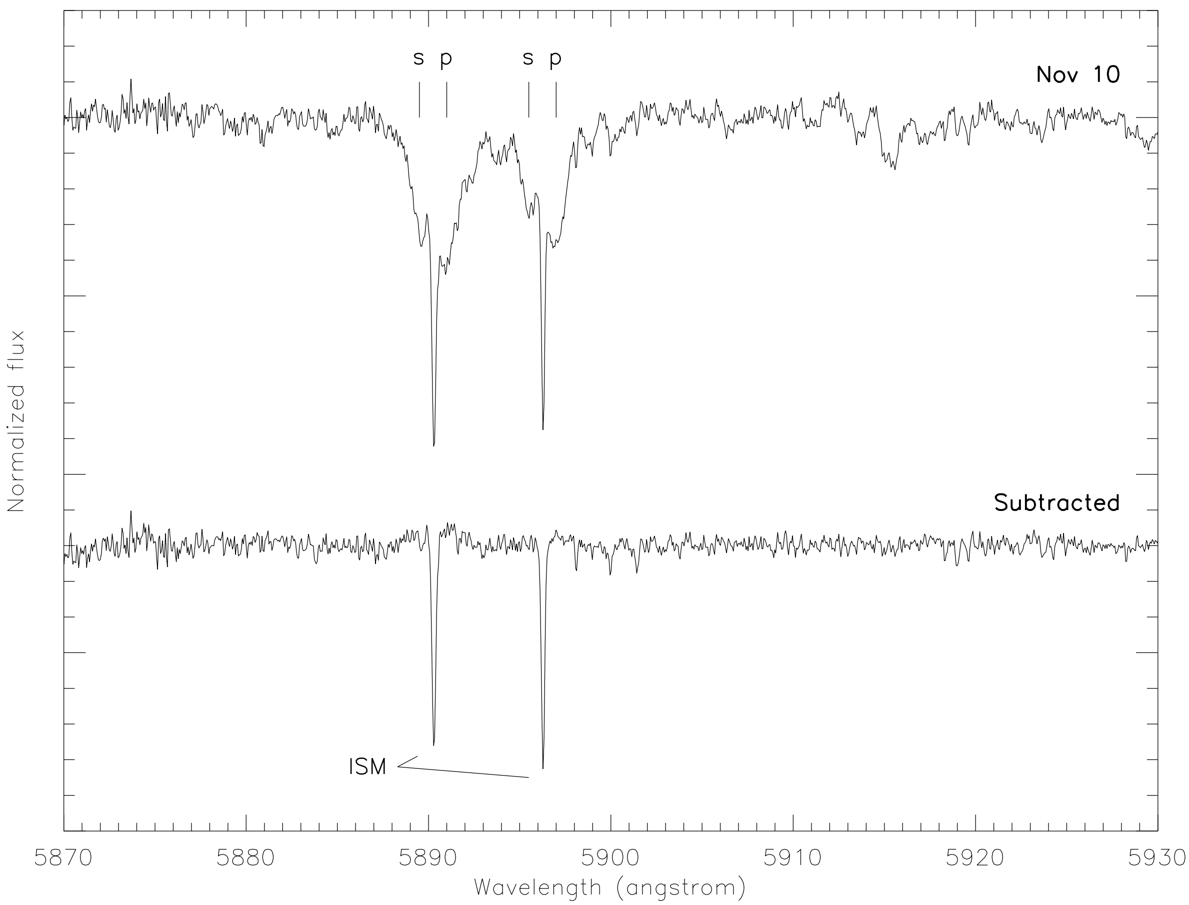

Fig. 5.— Normalized spectrum of TYC 8380-1953-1 during Nov 10, 2011 showing the Na I doublet of both stars in the system and the narrow-absorption component associated with interstellar medium. The spectrum at the bottom is the result of subtracting the synthetic photospheric spectrum of TYC 8380-1953-1 created with JSTARMOD from the observed spectrum of β Ceti (see Section 3.2.1 for details).

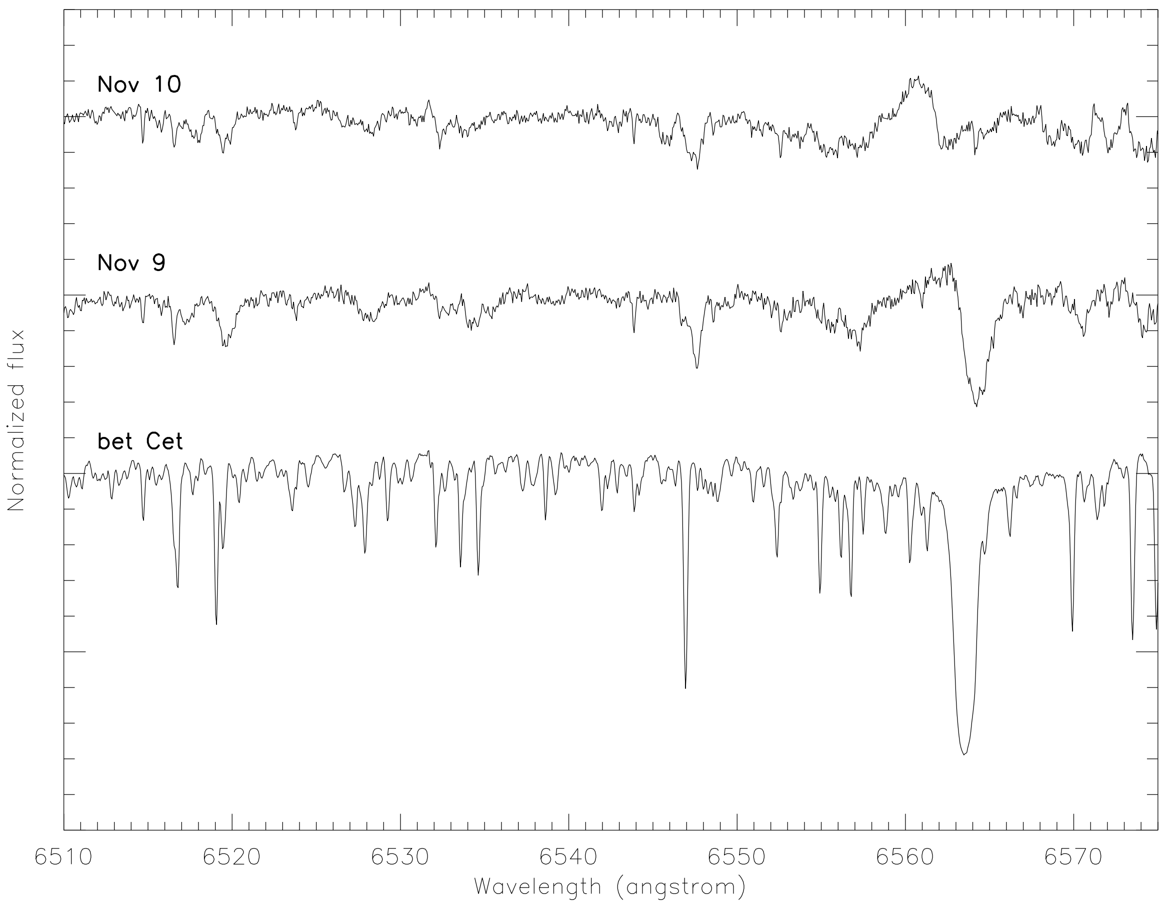

Fig. 6.— Normalized spectra of TYC 8380-1953-1 and β Ceti in the region of the Hα line during Nov 9 and 10, 2011.

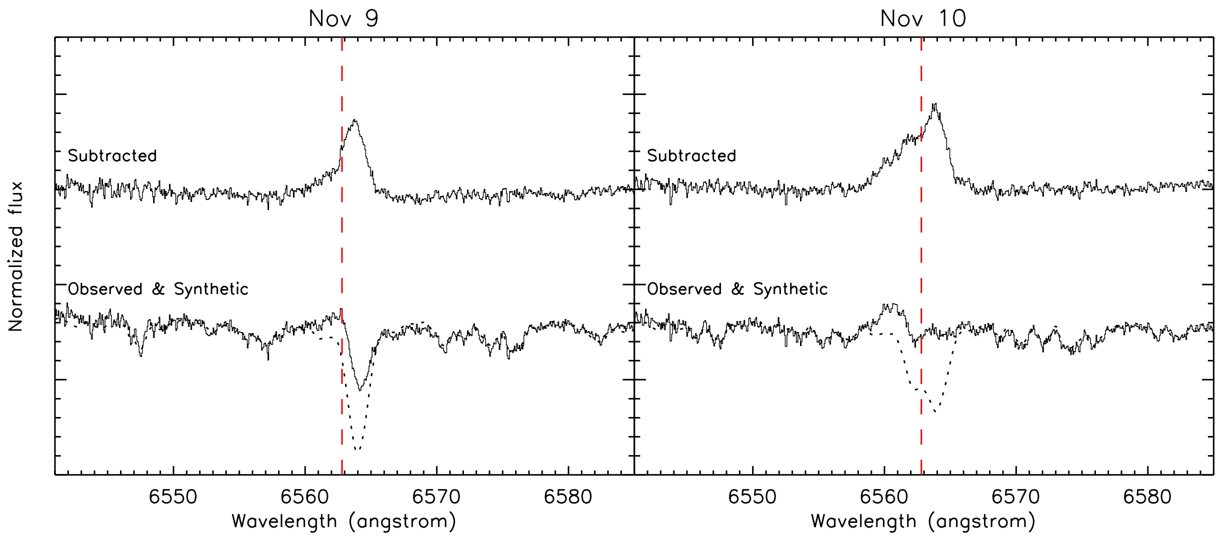

Fig. 7.— Hα subtracted spectrum of TYC 8380-1953-1 for observations performed in Nov 9 and 10. Dashed lines are the synthetic spectra obtained with JSTARMOD. Continuous lines are used for the observed and the subtracted spectra. The vertical dashed line in both panels marks the laboratory wavelength for the Hα line ($V_{\rm r} = 0$ km s^{-1}).

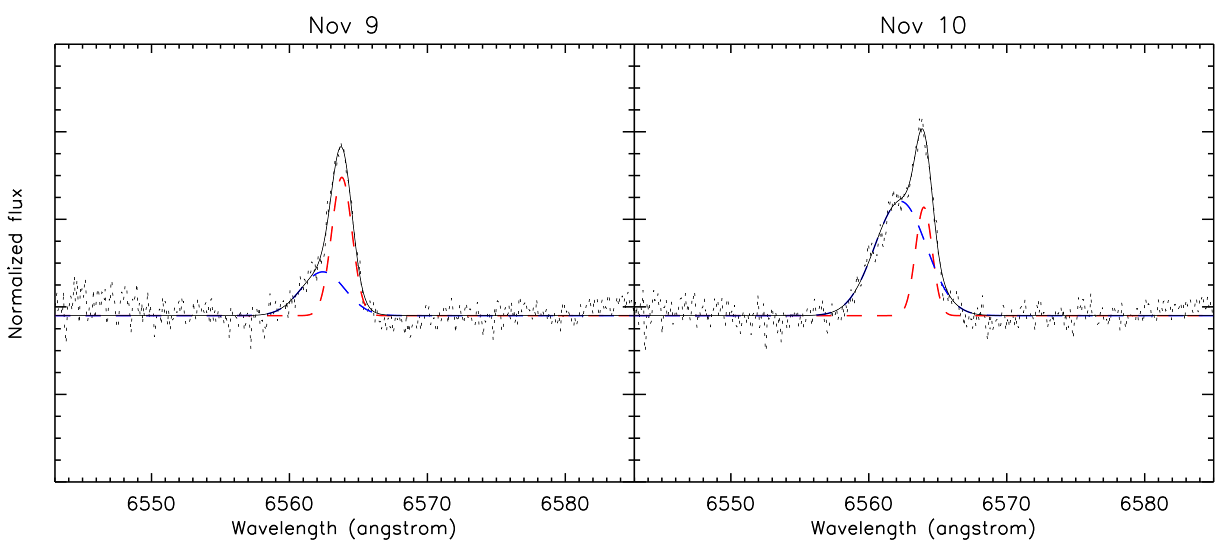

Fig. 8.— Modeling of the chromospheric Hα emission of TYC 8380-1953-1 by two Gaussians. In each panel, the subtracted spectrum is plotted as a dotted-line. The continuous line is the fitted function and the dashed lines are the two Gaussians corresponding to the two stars of the binary system.

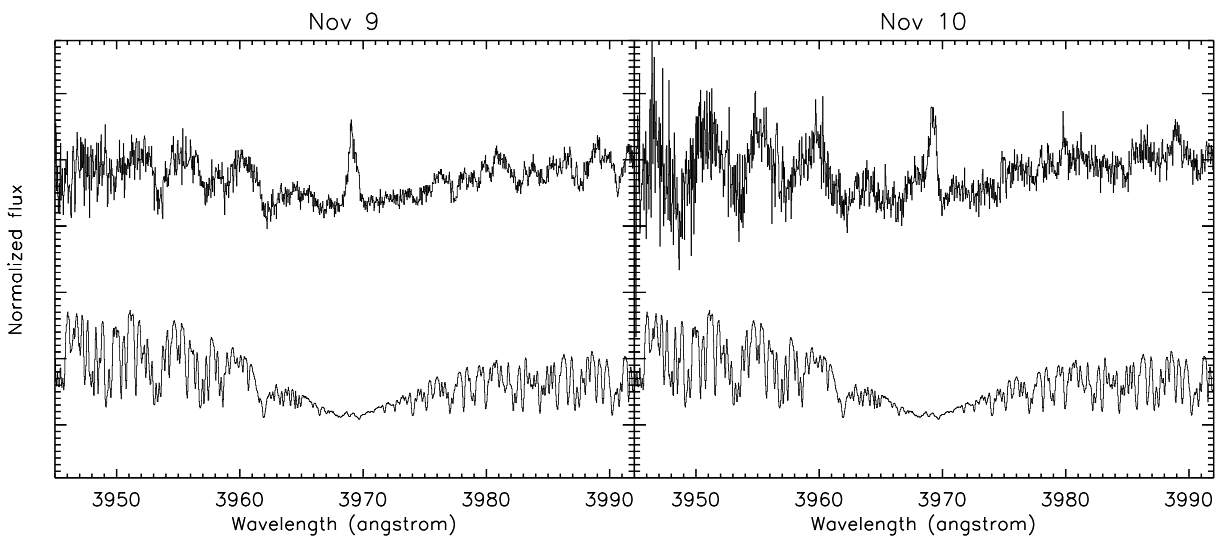

Fig. 9.— Normalized spectrum in the region of Ca II H for TYC 8380-1953-1 (up) and β Cet (bottom) during Nov 9 and 10.

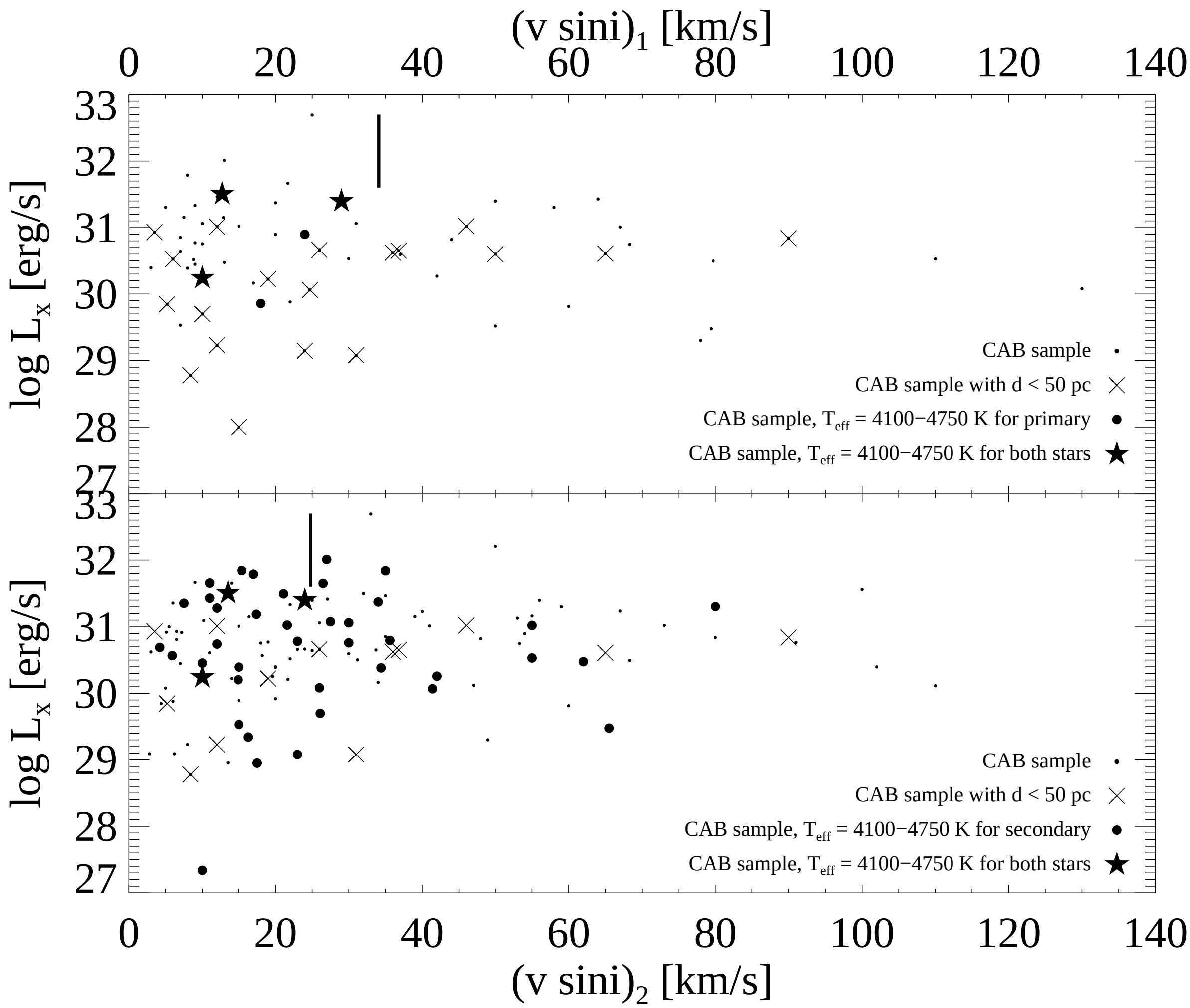

Fig. 10.— X-ray luminosity versus projected rotational velocity ($v \sin i$) for the primary and secondary components of binary systems in Eker et al. (2008), top and bottom panels respectively. TYC 8380-1953-1 is shown as vertical line for the range of L_X from the pointed *XMM-Newton* observation for d=600-2000 pc.